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(58) Field of search

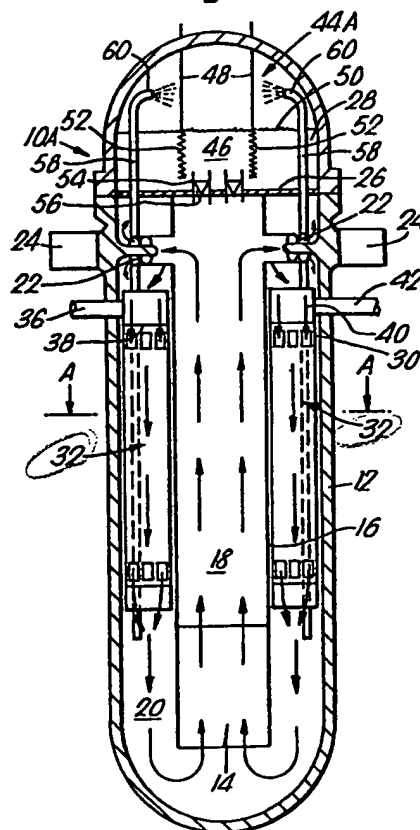
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(54) An improved water cooled nuclear reactor and pressuriser assembly

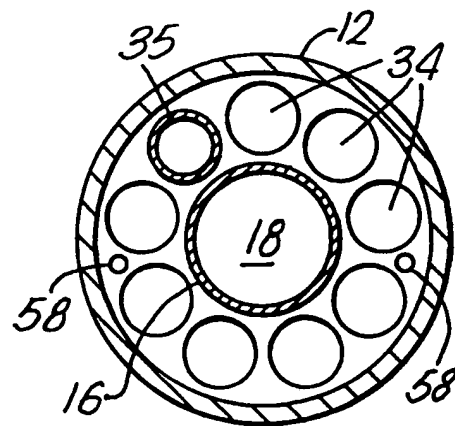
(57) A water cooled nuclear reactor (10A) comprises a reactor core (14), a primary water coolant circuit (18, 20) and a pressuriser (44A) arranged as an integral unit in a pressure vessel (12). The pressure vessel (12) is divided into an upper chamber (28) and a lower chamber (30) by a casing (26), the reactor core (14) and primary water coolant circuit (18, 20) are arranged in the lower chamber (30) and the pressuriser (44A) is arranged in the upper chamber (28).

A plurality of spray pipes (58) interconnect a steam space (48) of the pressuriser (44A) with the downcomer (20) of the primary water coolant circuit (18, 20) below a heat exchanger (32). A plurality of surge ports (54) interconnect a water space (46) of the pressuriser (44A) with the primary water coolant circuit (18, 20). The surge ports (54) have hydraulic diodes (56) so that there is a low flow resistance for water from the water space (46) of the pressuriser (44A) to the primary water coolant circuit (18, 20) and high flow resistance in the opposite direction. The spray pipes (58) provide a desuperheating spray of cooled water into the pressuriser (44A) during positive volume surges of the primary water coolant. The pressuriser arrangement may also be applied to integral water cooled reactors with separate pressurisers and to dispersed pressurised water reactors. The surge ports also allow water to flow by gravity to the core in an emergency.

Fig.1.



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AN IMPROVED WATER COOLED NUCLEAR REACTOR  
AND PRESSURISER ASSEMBLY

The present invention primarily relates to integral water cooled nuclear reactors with pressurisers, and is particularly applicable to water cooled nuclear reactors of the integral pressurised water reactor (PWR) type. However the invention is also applicable to integral water cooled nuclear reactors with separate pressurisers and to dispersed PWR's with separate pressurisers.

The present invention is particularly suitable for use with light water, the invention is also applicable for use with heavy water moderated water cooled reactor types.

The present invention seeks to provide an improved water cooled nuclear reactor and pressuriser assembly which controls compression of pressuriser steam space during positive primary coolant volume surge.

Accordingly the present invention provides a water cooled nuclear reactor and pressuriser assembly comprising a reactor core, a primary water coolant circuit arranged to cool the reactor core, a pressuriser, the reactor core and at least a portion of the primary water coolant circuit being enclosed by a pressure vessel, the pressuriser having a water space and a steam space, at least a portion of the water space of the pressuriser being positioned above an upper portion of the primary water coolant circuit, at least one spray means which communicates between the pressuriser and the primary water coolant circuit to connect the steam space of the pressuriser with a portion of the primary water coolant circuit positioned below any normal effective water level range of the primary water coolant circuit, at least one surge port means which communicates between the pressuriser and the primary water coolant circuit to connect the water space of the pressuriser with a portion of the primary water coolant circuit positioned below any normal effective water level range of the primary water coolant circuit, the at least one surge port means being arranged to have relatively low flow resistance for water from the water

space of the pressuriser to the primary water coolant circuit and relatively high flow resistance for water from the primary water coolant circuit to the water space of the pressuriser whereby the at least one spray means which communicates between the steam space of the pressuriser and the upper portion of the primary water coolant circuit allows water in the primary water coolant circuit to flow to the steam space of the pressuriser to provide a desuperheating spray of water into the steam space of the pressuriser.

The reactor core may be arranged in the lower region of the pressure vessel, the primary water coolant circuit comprising a riser passage to convey relatively hot water and steam to at least one heat exchanger, and a downcomer passage to convey relatively cool water from the at least one heat exchanger to the reactor core.

The at least one heat exchanger may be positioned in an upper region of the downcomer passage.

The at least one heat exchanger may be a steam generator.

The primary water coolant circuit may comprise at least one pump to assist the circulation of primary water coolant.

The reactor core, the primary coolant circuit and the pressuriser may be arranged as an integral unit enclosed by the pressure vessel, at least one casing being arranged in the pressure vessel to substantially divide the pressure vessel into a first chamber and a second chamber, the reactor core and the primary coolant circuit being arranged in the second chamber, the pressuriser being arranged in the first chamber, the casing preventing interaction between the water in the primary water coolant circuit and the water in the water space of the pressuriser.

The pressuriser may form a surge tank positioned in the first chamber, the surge tank being defined by the pressure vessel and the casing.

A peripheral region of the casing may be secured to the pressure vessel.

The casing may be arranged to divide the pressure vessel into a first vertically upper chamber and a second vertically lower chamber.

At least one spray means may communicate between the pressuriser and the primary water coolant circuit to connect the steam space of the pressuriser with a portion of the primary water coolant circuit positioned in the downcomer below the heat exchanger.

At least one of the spray means may comprise a spring nozzle.

The at least one surge port means may connect a lower portion of the water space of the surge tank with a portion of the downcomer passage in the region of the heat exchanger.

The at least one surge port means may connect a lower portion of the water space of the surge tank with a lower portion of the downcomer passage below the heat exchanger.

The riser passage may be defined by a hollow cylindrical member, the downcomer passage being defined between the hollow cylindrical member and the at least a part of the pressure vessel.

The at least one surge port means may comprise a hydraulic diode.

The water cooled nuclear reactor may be an integral pressurised water reactor.

The pressuriser may have heating means to heat the water in the waterspace.

The pressuriser may be a separate pressuriser.

The present invention will be more fully described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a vertical cross-sectional diagrammatical view of a water cooled nuclear reactor with integral pressuriser according to the present invention.

Figure 2 is a cross-sectional view in the direction of arrows A-A in Figure 1.

A water cooled PWR nuclear reactor 10A with integral pressuriser 44A according to the present invention is shown in Figures 1 and 2.

The water cooled PWR nuclear reactor 10A comprises a pressure vessel 12 within which is positioned a reactor core 14. The reactor core 14 is positioned substantially at the lower region of the pressure vessel 12, and the reactor core 14 includes a system of movable neutron absorbing control rods linked to drive mechanisms (not shown). A neutron reflector surrounds the reactor core 14 and a thermal shield is positioned below the reactor core 14, and thermal shields are positioned so as to surround the neutron reflector. The thermal shields protect the pressure vessel 12 from radiation emanating from the reactor core 14.

A primary water coolant circuit is used to cool the reactor core 14, and the primary water coolant circuit uses a pumped flow or a natural circulating arrangement. The primary water coolant circuit comprises a hollow cylindrical member 16 which is aligned with and positioned vertically above the reactor core 14 to define a riser passage 18 therein for the natural vertically upward flow of relatively hot primary coolant from the reactor core 14, and an annular downcomer passage 20 is defined with the pressure vessel 12 for the natural vertically downward return flow of relatively cool primary coolant to the reactor core 14. The primary water coolant circuit is also provided with one or more pumps 22, which are driven by motor 24. The pumps 22 are positioned in the downcomer passage 20.

A casing 26 is positioned in the pressure vessel 12, and divides the pressure vessel 12 into a first vertically upper chamber 28 and a second vertically lower chamber 30. The reactor core 14 and the primary water coolant circuit are arranged in the lower chamber 30.

A secondary coolant circuit takes heat from the primary water coolant circuit. The secondary coolant circuit comprises a heat exchanger 32 which is positioned coaxially in the upper region of the annular downcomer passage 20.

The heat exchanger 32 comprises one or more heat exchanger modules 34 which are arranged in an annulus formed by the cylindrical member 16 and the pressure vessel 12. The heat exchanger modules 34 comprise one or more tubes which receive secondary coolant from a supply of secondary coolant via a supply pipe 36 and inlet header 38 and which supply heated secondary coolant via an outlet header 40 and a supply pipe 42 for driving an electrical turbo-generator, for district heating, process heat or a propulsion system.

The tubes of the heat exchanger modules 34 extend through an annular shroud 35, these shrouds 35 are interconnected at their upper ends, and are secured and sealed to the pressure vessel 12 and the hollow cylindrical member 16 to prevent the flow of primary coolant through the interstitial regions of the downcomer 20 between the heat exchanger modules 34 shrouds 35. Thus the primary water coolant flows through the heat exchanger shrouds 35 to facilitate effective primary coolant flow distribution through the heat exchanger modules 34.

The heat exchanger 32 in this example is a steam generator, and the secondary coolant used is water. The steam generator could be a once through type or a recirculatory type with downcomer pipes between the outlet and inlet headers.

The casing 26 has an annular peripheral region which is secured to the pressure vessel 12.

The pressuriser 44 is positioned within the pressure vessel 12 in the vertically upper chamber 28 formed between the casing 26 and the pressure vessel 12. The pressuriser 44A forms a surge tank which contains water 46 and steam 48 separated by a water/steam interface or water level 50. One or more electrical immersion heaters 52 are provided in the pressuriser 44 positioned below the water level 50.

The casing 26 contains surge ports 54 which have hydraulic diodes 56 to effect a relatively low resistance to the flow of water from the pressuriser 44 water space 46 to

the primary water coolant circuit riser 18 and a relatively high resistance to the flow of water from the primary water coolant circuit to the pressuriser 44 water space 46 through the surge ports 54.

It may be equally possible to arrange the size geometry and location of the lower end of the surge ports 54 so that the surge ports 54 have these characteristics.

One or more large diameter spray pipes 58 interconnect the steam space 48 of the pressuriser 44 with the downcomer 20 portion of the primary coolant circuit, as shown the spray pipes 58 extend from the pressuriser steam space 48 through the pressuriser water space 46 and through the casing 26.

The spray pipes 58 descend from the casing 26 through the interstitial regions of the downcomer 20 between the heat exchanger modules 34 to a position in the downcomer 20 below the heat exchanger 32. The spray pipes 58 are provided with spray nozzles 60 at their upper ends.

In operation the spray pipes 58 provide a desuperheating spray of subcooled water into the pressuriser steam space 48 during rapid surges of primary water coolant from the primary water coolant circuit to the pressuriser 44A. Flow of water from the primary water coolant circuit to the pressuriser 44A steam space 48 is facilitated by endowing the alternative flow path via the surge ports 54 with a relatively high resistance to flow from the primary water coolant circuit to the pressuriser water space 46. This may be effected by hydraulic diodes 56 in the surge ports 54. A rapid flow of water into the water space 46 of the pressuriser 44A results in a piston-like compression of the pressuriser steam space 48 by the rising water level 50. Surge flow diverted through the spray pipes 58 lessens the piston effect and facilitates desuperheating of the steam space 48 by mixing. To facilitate mixing of the surge flow from the spray pipes 58 into the steam space 48 the spray pipes 58 are fitted with spray nozzles 60. This arrangement



effectively taps the power imbalance during a positive primary coolant volume surge to drive the desuperheating spray flow through the spray pipes 58 to the pressuriser steam space 48.

The transient surge flow through the spray pipes 58 is sprayed into the pressuriser steam space 48 during a positive volume surge, and because the spray pipes 58 are connected to the primary water coolant circuit below the heat exchangers 34 in the downcomer 20 the spray will be initially cool making the spray more effective.

The surge ports 54 have a low resistance to flow of water from the pressuriser water space 46 to the primary water coolant circuit. This facilitates augmentation of the primary water coolant inventory during negative volume surges accompanying transient reductions in primary water coolant circuit temperature or transient increases in primary water coolant circuit effective water level.

A low flow resistance also facilitates gravity draining of water coolant from the water space 46 of the pressuriser into the primary water coolant circuit during accident conditions.

It is preferable that the surge ports 54 and spray pipes 58 terminate at the same height, and both the surge ports 54 and the spray pipes 58 must extend downwards into either the downcomer passage 20 or the riser passage 18.

The invention is also applicable to integral water cooled nuclear reactors with separate pressurisers and to dispersed PWRs with separate pressurisers.

## Claims:-

1. A water cooled nuclear reactor and pressuriser assembly comprising a reactor core, a primary water coolant circuit arranged to cool the reactor core, a pressuriser, the reactor core and at least a portion of the primary water coolant circuit being enclosed by a pressure vessel, the pressuriser having a water space and a steam space, at least a portion of the water space of the pressuriser being positioned above an upper portion of the primary water coolant circuit, at least one spray means which communicates between the pressuriser and the primary water coolant circuit to connect the steam space of the pressuriser with a portion of the primary water coolant circuit positioned below any normal effective water level range of the primary water coolant circuit, at least one surge port means which communicates between the pressuriser and the primary water coolant circuit to connect the water space of the pressuriser with a portion of the primary water coolant circuit positioned below any normal effective water level range of the primary water coolant circuit, the at least one surge port means being arranged to have relatively low flow resistance for water from the water space of the pressuriser to the primary water coolant circuit and relatively high flow resistance for water from the primary water coolant circuit to the water space of the pressuriser whereby the at least one spray means which communicates between the steam space of the pressuriser and the portion of the primary water coolant circuit allows water in the primary water coolant circuit to flow to the steam space of the pressuriser to provide a desuperheating spray of water into the steam space of the pressuriser.

2. A water cooled nuclear reactor as claimed in claim 1 in which the reactor core is arranged in the lower region of the pressure vessel, the primary water coolant circuit comprising a riser passage to convey relatively hot water and steam to at least one heat exchanger, and a downcomer

passage to convey relatively cool water from the at least one heat exchanger to the reactor core.

3. A water cooled nuclear reactor as claimed in claim 2 in which the at least one heat exchanger is positioned in an upper region of the downcomer passage.

4. A water cooled nuclear reactor as claimed in claim 3 in which the at least one heat exchanger is a steam generator.

5. A water cooled nuclear reactor as claimed in any of claims 1 to 4 in which the primary water coolant circuit comprises at least one pump to assist the circulation of primary water coolant.

6. A water cooled nuclear reactor as claimed in any of claims 1 to 5 in which the reactor core, the primary coolant circuit and the pressuriser are arranged as an integral unit enclosed by the pressure vessel, at least one casing being arranged in the pressure vessel to substantially divide the pressure vessel into a first chamber and a second chamber, the reactor core and the primary coolant circuit being arranged in the second chamber, the pressuriser being arranged in the first chamber, the casing preventing interaction between the water in the primary water coolant circuit and the water in the water space of the pressuriser.

7. A water cooled nuclear reactor as claimed in claim 6 in which the pressuriser forms a surge tank positioned in the first chamber, the surge tank being defined by the pressure vessel and the casing.

8. A water cooled nuclear reactor as claimed in claim 7 in which a peripheral region of the casing is secured to the pressure vessel.

9. A water cooled nuclear reactor as claimed in claim 6, claim 7 or claim 8 in which the casing is arranged to divide the pressure vessel into a first vertically upper chamber and a second vertically lower chamber.

10. A water cooled nuclear reactor as claimed in claim 7, claim 8 or claim 9, in which the at least one surge port means connects a lower portion of the water space of the

surge tank with a portion of the downcomer passage in the region of the heat exchanger.

11. A water cooled nuclear reactor as claimed in claim 7, claim 8 or claim 9 in which the at least one surge port means connects a lower portion of the water space of the surge tank with a lower portion of the downcomer passage below the heat exchanger.

12. A water cooled nuclear reactor as claimed in any of claims 1 to 11 in which the riser passage is defined by a hollow cylindrical member, the downcomer passage being defined between the hollow cylindrical member and the at least a part of the pressure vessel.

13. A water cooled nuclear reactor as claimed in any of claims 1 to 12 in which the at least one surge port means comprises a hydraulic diode.

14. A water cooled nuclear reactor as claimed in any of claims 1 to 13 in which at least one spray means communicates between the pressuriser and the primary water coolant circuit to connect the steam space of the pressuriser with a portion of the primary water coolant circuit positioned in the downcomer below the heat exchanger.

15. A water cooled nuclear reactor as claimed in claim 14 in which at least one of the spray means comprises a spray nozzle.

16. A water cooled nuclear reactor as claimed in any of claims 1 to 15 in which the water cooled nuclear reactor is an integral ~~pressurised~~ water reactor.

17. A water cooled nuclear reactor as claimed in claim 16 in which the pressuriser has heating means to heat the water in the water space.

18. A water cooled nuclear reactor as claimed in any of claims 1 to 5 in which the pressuriser is a separate pressuriser.

19. A water cooled nuclear reactor as claimed in claim 18 in which the water cooled nuclear reactor is an integral pressurised water reactor.

20. A water cooled nuclear reactor and pressuriser assembly substantially as hereinbefore described with reference to and as shown in Figures 1 to 2.